HIGH FREQUENCY PROPAGATION STUDIES IN THE COASTAL ENVIRONMENT

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LONG-TERM GOAL

To learn how small scale physical and biological processes contribute to the scattering of high frequency acoustic signals. To understand the relationship between turbulent boundary layers, turbulent mixing and related phenomena and the scattered acoustic signal. To develop models of these processes

SCIENTIFIC OBJECTIVES

To carry out high frequency propagation experiments through a shallow water environment and interpret the results in terms of contributions due to bubbles, turbulent velocity and sound speed fluctuations.

APPROACH

Our approach has been to conduct high frequency (50kHz-300kHz) propagation experiments over modest ranges (300m-2km) using multiple sources and receivers rigidly fixed to the sea floor. The experiments have been carried out in a variety of environments including channel flows and surf zones, using different transducer configurations (horizontal and 2-d arrays). Independent measurements have been acquired of the relevant scattering and refractive variability, including measurements of turbulent dissipation with a moored microstructure sensor (in collaboration with R Lueck, U Victoria), horizontally directed and vertically directed incoherent Doppler sonars, coherent Doppler measurements of fine scale velocity structure, and measurements of the complex dispersion relationship resulting from bubble suspensions. Work has been carried out collaboratively with Daniela DiIorio (SACLANT), with Grant Deane (Scripps) and with several groups involved in the Scripps Pier experiment.

WORK COMPLETED

(i) Analysis of reciprocal transmission data acquired in Cordova Channel has been completed, allowing comparison with available theory of the contributions from scalar and vector components to the effective structure parameter. (ii) An experiment was conducted off Scripps Pier in which a combination of horizontal propagation and horizontal Doppler back scatter measurements were acquired along a path nearly orthogonal to the beach, together with detailed observations of bubble size distributions both in the surf zone and on a triangular propagation frame. (iii) A reciprocal transmission scintillation array was deployed in the Bosphorus and preliminary data acquired.

RESULTS

Measurements of 67kHz reciprocal transmission over a 700m path in a turbulent channel flow have been decomposed into vector and scalar components with a resolution of ~1mm/s for both path averaged sound speed and flow speed. A comparison of the relative contributions of vector and scalar components to the effective structure parameter have been shown to be generally consistent with predictions of Ostashev's (1991) theory (DiIorio & Farmer, 1997). Path averaged measurements of the turbulence dissipation derived from the separated vector component was found to be consistent with independent measurements of dissipation measured at mid-channel by R Lueck with a moored microstructure sensor. Preliminary results of acoustical propagation in the Bosphorus have also been acquired, but not as yet analysed.

Measurements of 100kHz propagation over a ~200m path from the end of Scripps Pier into the surf, provide time series measurements of changing propagation conditions as the bubble clouds vary in intensity (Farmer & Vagle 1997). At times the propagation is completely obscured; during the moments preceding signal loss, or following signal recovery, the travel time appears to increase noticeably. Interpretation of these signals is aided by simultaneous Doppler back scatter measurements along the same, and adjacent, paths. The backscatter signals show evolution of the wave train and the generation of bubble clouds in the surface, as well aperiodic advection of bubbles in the rip current, towards the NRL measurement frame. Measurements of bubble size distributions in the surf made concurrently with coherent Doppler measurements of turbulent velocity show maximum attenuation at 30kHz associated with dense bubble distributions. Turbulent dissipation measured with the coherent Doppler shows a corresponding increase within the bubble cloud immediately following wave breaking (Figure 1), but the turbulence decay occurs rapidly than decay of the bubble cloud which can persist for ~150s. A self contained bubble sensor based on the resonator concept has been designed, built and tested in both coastal and open ocean environments and a detailed theory for its performance has been developed (Farmer, Vagle & Booth, 1997).

IMPACT/APPLICATION

High frequency propagation in coastal and near surface waters is sensitive to refractive variability and scattering effects. Such effects can adversely influence performance of synthetic aperture sonars and other systems that depend on phase coherent propagation. Conversely, variability in measured signals can be inverted so as to learn more about the processes such as turbulence and bubble distributions, that are responsible. The observations acquired here directly relate to the practical application of high frequency acoustical propagation in coastal and upper ocean waters and are expected to lead to insights on factors affecting performance of imaging and communication systems.

REFERENCES

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Ostachev, V.E., Propagation and scattering of sound waves in the turbulent media (atmosphere or ocean), Atmos. Opt. 4, 653-656, 1991.

Figure Caption:

Figure 1.   Breaking wave activity off Scripps pier. *Top:* Velocity fine structure measured with coherent Doppler. *Middle:* Turbulence dissipation ε derived from Doppler (black line); air fraction derived from acoustical resonator (red dashed line). *Bottom:* Number N(a) of bubbles/micron radius increment/m^3, against bubble radius, for the indicated sample time. Bubble measurements are made twice a second.